SYNOPSIS

"Synthesis of Nano-Structured Mixed Metal Chalcogenide Thin Films Using Spray Pyrolysis Technique for Development of Highly Sensitive and Ultra Fast Photo-Detector"

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Title

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1. Introduction

Materials utilized for device fabrication (such as field effect transistors, sensors, solar cells, light emitting diodes and photo-detectors) micro or nano structures semiconductors are playing main role in its functionality and recently cultivated interest among the researcher [1-5]. Among all materials, semiconducting materials have specific property which makes it photo-sensitive [5-6]. The most important device made using photo-sensitive semiconducting material is photo-detector, which is a essential device used in many applications, such as imaging, fiber optical communication, environmental monitoring, light sensing, surveillance systems, space [1-5], etc.

The photo-detectors used in these applications must have high photosensitivity, fast response speed, good stability, high reliability, low cost and long lifetime. Most of the photo-detectors work on two principles; first deals with generation of photo excited charge carriers and second deals with transport of these charge carriers. These two processes may get hinder due to presence of defects or chemo/physico adsorption of atmospheric oxygen [2]. In addition to this, the photo-detector is expected to work in hard environmental condition like temperature, humidity, magnetic field, EM field, radiation, etc. which degrade the device properties.

Among all materials II-VI group compounds received importance among researchers due to its promising properties of high optical absorbance and direct band gaps corresponding to a wide solar spectrum. A large variety of techniques including hybrid techniques have been utilized for synthesizing these films. The physical properties of these materials can be controlled smoothly via optimizing the molar composition of the basic ingredients. Owing to the combination of these properties, a possible mixed metal chalcogenides thin-film or heterostructures can be synthesized for creating a wide spectrum photo-detector.

2. Review of Literature and Development in the Subject:

Solution processed metal chalcogenides nanostructures / thin films are traditionally studied for its applications in optoelectronics, sensors, etc. devices due to their unique structural, electrical and optical properties. In recent years, their band gap and related absorption coefficient cab ne tuned easily to make them attractive material in photo-detection applications. For example,

K. Deng, et.al has reported an overview of recent research about CdS nanoscale photodetectors, where metal-semiconductor contact types are discussed in detail: Ohmic contact, Schottky contact and field enhanced transistor configuration [7].

J. P. Enriquez, et.al studied synthesis of CdS films of different thicknesses via chemical bath deposition and the photo-response studies indicate that the film

thickness has an influence on the current decay under dark. The observed opto-electronic properties were attributed to the crystallite size and internal microstrain [8]

M. Husham, et.al reported that the molar concentration of reagents effect on the quality of the deposited thin films. Structural and morphological properties of the grown CdS thin films was significantly affected by molar concentrations of reagents. Optimal thin film quality was utilized to fabricate a nanocrystalline CdS-based optical sensor [9].

R. Saran, et.al reviewed that lead sulphide (PbS) nanocrystals are emerging as one of the most promising new materials for photodetector fabrication. This materials advantages are low-cost manufacturing, solution processability, size-tunable spectral sensitivity and flexible substrate compatibility, and they have achieved figures of merit outperforming conventional photodetectors [10].

D. Vankhade, et.al has demonstrated deposition of band gap tunable PbS thin films. The process for deposition of PbS films is simple, at atmospheric pressure and at low temperatures. Moreover, the as-deposited films are photoconducting in nature [11].

Many researchers try to enhance the properties of this via modulating the surface or bulk, as
Pei et.al has proposed that CdS nanowires network fabricated on mixed cellulose esters membrane show enhanced photosensitivity due to the polymer molecules, which occupy the surface Vs sites leading to the fast photoresponse of this device [12].
Shin et.al reports excellent property of nitrocellulose (NC) as a passivation layers or barrier against adsorption of ambient gases on amorphous indium gallium zinc oxide thin film transistors [13].

3. Objectives of Research/proposed Hypothesis:

This work investigates the photoconducting properties of mixed metal chalcogenide thin films synthesized using spray pyrolysis technique and possible development of highly sensitive and fast responsive optoelectronic device using the deposited film. To achieve the above mention objective this work is made of specific aims;

1. To synthesize metal chalcogenide (CdS, PbS) and mixed chalcogenide (CdS-PbS) thin film (pure or doped) on glass/polymer substrate using spray pyrolysis technique.
2. To characterize synthesized thin films using XRD, UV–Vis spectroscopy, Raman spectroscopy, TGA-DTA, SEM-EDS, XPS, etc.
3. To study the photo–conducting properties of thin film samples using dedicated optoelectronic characterization setup. This includes responsivity, detectivity, response (rise/decay) time, sensitivity, gain, etc.

4. To probe the electronic structure of the film using X-ray photoelectron spectroscopy and understanding the role of its intrinsic properties on charge transport
5. To propose effective photo–detector device based on the results and material properties.

4. Methodology to be adopted

This work includes synthesis of metal chalcogenide (CdS, PbS) and mixed chalcogenide (CdS-PbS) thin film (pure or doped) for its viable application in development of optoelectronic device application. This work designed to run on three stages;

Stage-1*:* Fabrication of thin films of metal sulfide***:*** The motivation behind this stage is to investigate the growth and physical properties of amorphous and polycrystalline metal chalcogenide (CdS, PbS) and mixed chalcogenide (CdS-PbS) thin film films grown on glass / polymer substrate.

Stage 2: Establish the electronic structure of the films and correlate with its photoconducting property***:*** In this stage the electronic structure of the pure or mixed thin films was investigated using X-ray photoelectron spectroscopy. The obtained results were correlated with the role of deposition parameters, mixing concentration and film thickness with the observed photoconducting properties.

Stage 3: Development of optoelectronic device based on the obtained results: The aim of this stage is to study the photo-conducting properties of the pure and mixed thin films. The results of the investigation will be used to fabricate viable photo-detector based on mixed material.

5. Importance of study/ Society application:

National Status: A number of important research outcomes addressing a variety of issues in this field are supported and many are in various National laboratories and Universities in the country funded by Government of India. Although it is difficult to summarize the whole effort, a representative cross section of ideas and strategies can be provided as follows: Dr. S. B. Ogale, Dr. G. U. Kulkarni Dr. D. J. Late, Dr. S. M. Jejurikar, Dr.Keshav Rajpure, Dr. S. S. Islam, Dr. Rajendra Singh, Dr. S. H. Husale, Dr. Abha Misra, etc.

International status: In the specific research area to be focused upon in this work, the international research is growing and creating an open opportunities for Indian science to take a lead and make a substantial impact. These developments are occurring in the

domains of new device concepts. Few impressive examples who flourish the focus of this project are:Dr. S. Sawyer, Dr. U. Jeong, Dr. Z. L. Wang, Dr. Y. A. Zhang, Dr. H. J. Kim, etc. Lots of literature is available on various reputed research journals like;Nature, Science, Advanced Materials, Nano Letters, Advanced Functional Materials, etc.

Significance of the study: In recent years, extensive research is going on in the area of synthesis of highly functional material owing to its promising applications in the field of opto or nano-electronic devices. Recent reports has shown mixed metal cghalcogenide material based light-emitting diodes, photo-detectors, solar cells, thin film transistors, etc. These thin films have been prepared by various physical and chemical methods, including vacuum evaporation, sputtering, electro deposition, molecular beam epitaxy, photochemical deposition, spray pyrolysis, metal organic chemical vapour deposition, chemical bath deposition, screen printing and sol-gel assisted spin coating method. All these techniques do have several merits and limitations. Among these techniques, the spin coating or spray pyrolysis method gives higher coating area, high superior homogeneity, high purity, better micro structural control and narrow thickness variation as compared with those prepared by physical methods. The spin coating or spray pyrolysis method have additional advantages like its simplicity, cost effectiveness and its ability to deposit uniform films, moreover, its reproducibility in a relatively shorter processing time at lower temperatures is remarkable. Current electronic industries need a method, which is low-cost, and large-scale integration.

This work focuses on the connectivity between the pure and mixed platforms based on photoconductivity in metal chalcogenide materials; emphasizing synergetic integration with potential for novel effects exclusive to the hybrid concept.

6**.Proposed work plan /formulation and structure of study: Year-wise Plan of work and targets to be achived**

First year:

a. Initiate synthesis of metal chalcogenide thin filmsemploying the available spray pyrolysis facilities.
b. Optimize parameters (solvent, concentration of chemicals, spray time, substrate temperature, etc.) of spray pyrolysis deposition technique.

Second Year:

a. Fabrication of metal contacts on the film for photoconductive mearurement.
b. Initiate testing of photo conducting properties of films with respect to intensity.
c. Based on the photoconducting measurement, optimize spray pyrolysis technique for getting functional thin films.

Third Year:

a. Study effect of deposition temperature and thickness on films structure and morphology.
b. Perform extensive in-house characterizations including AFM, XRD, TGA, etc. as well as those involving external collaborations SEM-EDS, TEM and XPS.

c. Testing photo-detection properties of the metal chalcogenide thin films with respective to wavelength.

Fourth Year:

a. Perform real time photo detection measurement on the fabricated device.
b. Estimate the photodetector parameters like responsivity, detectivity, sensitivity, photoresponse time, efficiency, nose equivalent power, gain, etc.

Fifth Year :

a. Review the status of progress during earlier years and to take appropriate steps towards the most effective utilization of the knowledge, facilities and experience during the remaining duration.
b. Continue to analyze the data obtained and proceed with publications/patenting as appropriate.
c. Prepare thesis for submission.

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